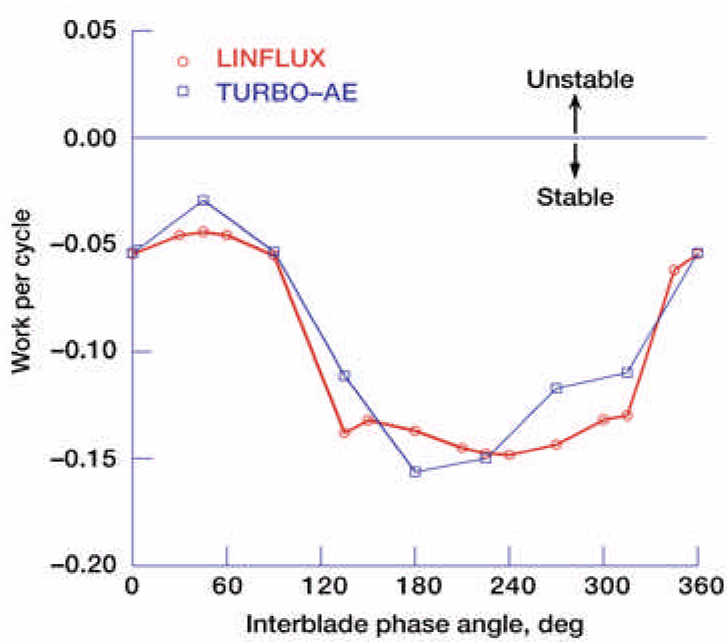
Fast-Running Aeroelastic Code Based on Unsteady Linearized Aerodynamic Solver Developed

The NASA Glenn Research Center has been developing aeroelastic analyses for turbomachines for use by NASA and industry. An aeroelastic analysis consists of a structural dynamic model, an unsteady aerodynamic model, and a procedure to couple the two models. The structural models are well developed. Hence, most of the development for the aeroelastic analysis of turbomachines has involved adapting and using unsteady aerodynamic models.

Two methods are used in developing unsteady aerodynamic analysis procedures for the flutter and forced response of turbomachines: (1) the time domain method and (2) the frequency domain method. Codes based on time domain methods require considerable computational time and, hence, cannot be used during the design process. Frequency domain methods eliminate the time dependence by assuming harmonic motion and, hence, require less computational time. Early frequency domain analyses methods neglected the important physics of steady loading on the analyses for simplicity. A fast-running unsteady aerodynamic code, LINFLUX, which includes steady loading and is based on the frequency domain method, has been modified for flutter and response calculations.

LINFLUX, solves unsteady linearized Euler equations for calculating the unsteady aerodynamic forces on the blades, starting from a steady nonlinear aerodynamic solution. First, we obtained a steady aerodynamic solution for a given flow condition using the nonlinear unsteady aerodynamic code TURBO. A blade vibration analysis was done to determine the frequencies and mode shapes of the vibrating blades, and an interface code was used to convert the steady aerodynamic solution to a form required by LINFLUX. A preprocessor was used to interpolate the mode shapes from the structural dynamic mesh onto the computational dynamics mesh. Then, we used LINFLUX to calculate the unsteady aerodynamic forces for a given mode, frequency, and phase angle. A postprocessor read these unsteady pressures and calculated the generalized aerodynamic forces, eigenvalues, and response amplitudes. The eigenvalues determine the flutter frequency and damping.

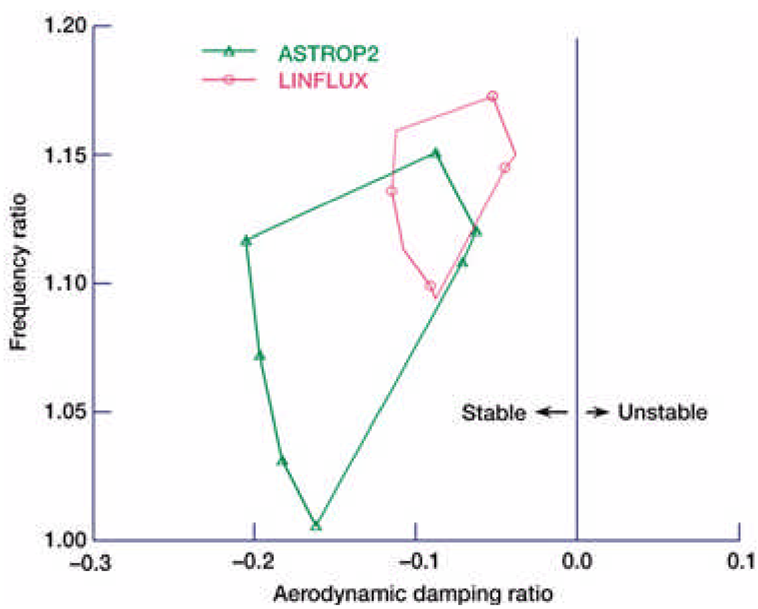
As a test case, the flutter of a helical fan was calculated with LINFLUX and compared with calculations from TURBO-AE, a nonlinear time domain code, and from ASTROP2, a code based on linear unsteady aerodynamics.



Work per cycle versus interblade phase angle for the pitching motion of a helical fan.

The preceding graph shows the work done per cycle for the pitching mode calculated by LINFLUX and TURBO-AE. The LINFLUX calculations show a very good comparison with TURBO-AE calculations.

The following graph shows the eigenvalues calculated for a helical fan. The calculations were plotted as frequency versus damping for the second mode. As seen in the figure, the predictions made with LINFLUX agree well with those made with ASTROP2.



Root locus plot showing frequency versus aerodynamic damping for the second mode of a helical fan.

The LINFLUX code was 6 to 7 times faster than the nonlinear time-domain code and can be used in the initial design phase. The aeroelastic development calculations described here were performed under a NASA grant by University of Toledo researchers in collaboration with Glenn researchers.

University of Toledo contacts: Dr. T.S.R. Reddy, 216-433-6083, Tondapu.S.Reddy@grc.nasa.gov; and Dr. Milind A. Bakhle, 216-433-6037, Milind.A.Bakhle@grc.nasa.gov
Authors: Dr. T.S.R. Reddy, Dr. Milind A. Bakhle, Oral Mehmed, and Prof. T. Keith, Jr.
Headquarters program office: OAT
Programs/Projects: Propulsion Systems R&T